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(54) **8-Phenyl xanthines.**

(57) The present invention relates to certain novel 8-phenylxanthines substituted in the 3 or 4 position of the phenyl group by an alkenylene, alkenyleneoxy, alkynylene or alkynyleneoxy bearing a terminal acidic grouping, and to their use in human and veterinary therapy, particularly for conditions associated with the cell surface effects of adenosine.

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NOVEL COMPOUNDS

The present invention relates to a class of novel xanthines and salts and solvates thereof, processes and intermediates for their preparation, pharmaceutical formulations containing them, and to their use in human and veterinary medicine.

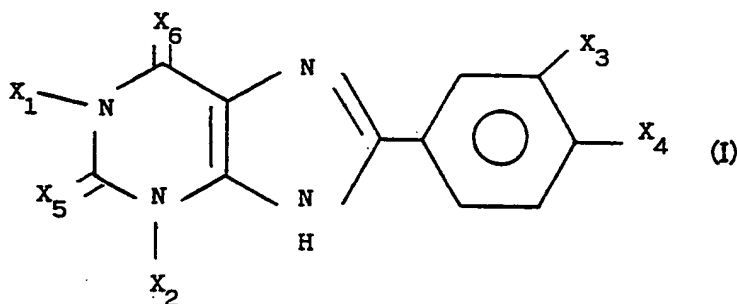
Theophylline, a naturally occurring alkaloid, is 1,3-dimethylxanthine and is known to antagonise the receptors for adenosine. Although its precise mechanism of action requires further clarification, it is believed that this property of theophylline accounts, at least to some extent, for its ability to stimulate the central nervous system and cardiac muscle, to act on the kidney to produce diuresis, and to relax smooth muscle, notably bronchial muscle (*Trends in Pharmacol. Sci.*, Jan 1980, **1**, 129 to 132; *Life Sci.*, 1981, **28**, 2083 to 2097; and *The Pharmacological Basis of Therapeutics*, 6th Edition, Macmillan Publishing Co, pages 592 to 607). Various derivatives of theophylline have been prepared in recent years including substituted 8-phenylxanthines that were prepared as part of a structure-activity study (*Biochem. Pharmacol.*, 1981, **30**, 325 to 333 and *Proc. Nat. Acad. Sci.*, 1983, **80**, 2077 to 2080). Some of these bind to adenosine receptors with greater affinity than theophylline - (European Patent Publication No. 92398).

A structurally distinct class of novel 8-phenylxanthines has now been discovered, which are characterised by the presence of an alkenylene, alkenyleneoxy, alkynylene or alkynyleneoxy moiety terminally substituted by an acidic grouping on the 3-or 4-position of the phenyl ring. These xanthine derivatives have been found to possess therapeutic

activity in their ability to antagonise the effects of adenosine in tissue preparations. Such activity is of therapeutic value in human and veterinary medicine and in particular for those pathophysiological disorders arising from the cell surface effects of adenosine.

Certain 8-phenylxanthines substituted by various groups on the pyrimidine and phenyl rings are described in UK Patent Application No. 2 135 311 A, reference being made to the adenosine antagonist activity of such compounds as measured by *in vitro* binding data only. However, the data provided in the Specification for the adenosine antagonist activity of such compounds illustrates that the binding of the compounds varies considerably according to the identity of the substituents on the pyrimidine and phenyl rings. The xanthine compounds according to the present invention constitute a structurally distinct class of 8-phenyl xanthines, characterised by the presence on the 3-or 4-position of the phenyl ring of an unsaturated grouping terminally substituted by an acidic grouping. These compounds have been found to possess advantageous adenosine antagonist activity as demonstrated by their response to the guinea pig ileum twitch test described hereinafter and, moreover, have shown superior activity to analogous compounds described in UK Patent Application No. 2 135 311 A, as shown in heart block models *in vivo* (described later.) The compounds are, thus, of therapeutic value.

Accordingly, the present invention provides a compound of formula (I):



wherein:

X₁ and X₂ are the same or different and are hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl or C₇₋₁₂ aralkyl optionally substituted in the aryl ring by C₁₋₆ alkyl, C₁₋₆ alkoxy, hydroxy, halo, nitro, amino, azido or cyano, provided that both X₁ and X₂ are not hydrogen;

one of X₃ and X₄ is hydrogen, C₁₋₆ alkyl, trifluoromethyl, C₁₋₆ alkoxy, halo, nitro, amino, C₁₋₆ alkoxycarbonyl or carboxy and the other is a group -Y-Z where Y is C₂₋₆ alkenylene, or C₃₋₆ alkenyleneoxy, C₂₋₆ alkynylene or C₃₋₆ alkynyleneoxy and Z is carboxy, sulphonyl or phosphonyl or a C₁₋₉ alkyl ester, a C₇₋₁₂ aralkyl ester or a C₆₋₁₂ aryl

ester thereof, or is 5-tetrazolyl; and

X₃ and X₄ are the same or different and are oxygen or sulphur; or a salt or solvate thereof.

The compounds of the invention may exist in a number of tautomeric forms and all such forms, individually and as mixtures, are embraced by the above definition of formula (I) even though only one tautomer is depicted for convenience.

A preferred sub-class of X₁ and X₂, when C₇₋₁₂ aralkyl optionally substituted in the aryl ring by C₁₋₆ alkyl, C₁₋₆ alkoxy, hydroxy, halo, nitro, amino, azido or cyano, is benzyl optionally substituted in the phenyl ring by methyl, methoxy, hydroxy, chloro, nitro, amino, azido or cyano. Examples included within this preferred sub-class include benzyl and benzyl substituted by nitro, amino, azido or cyano.

Preferably, X₁ and X₂ are the same or different and are hydrogen or C₁₋₆ alkyl. In particular, X₁ and X₂ are the same or different and are both C₁₋₆ alkyl. Examples of X₁ and X₂, when C₁₋₆ alkyl, include both branched and straight chain alkyl, for example

methyl, ethyl, n- and iso-propyl, and n -, iso- and tert-butyl. Preferred examples of X₁ and X₂, when C₁₋₆ alkyl, include ethyl, n-propyl and n-butyl, especially n-propyl.

Preferably, one of X₃ and X₄ is hydrogen.

A preferred sub-class of Y is (in straight-or branched-chain form)

C₂₋₃ alkenylene (such as vinylene, and propenyleneoxy) or C₂₋₆ alkynylene (such as acetylene). Most preferably, Y is vinylene or acetylene.

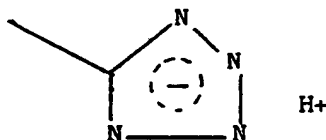
Preferably, Z, when a C₁₋₆ alkyl ester, is a C₁₋₆ alkyl ester. Examples of Z, when a C₁₋₆ alkyl ester, include the methyl and ethyl esters.

Examples of Z, when a C₇₋₁₂ aralkyl ester, include the benzyl ester.

Examples of Z, when a C₆₋₁₂ aryl ester, include the phenyl ester.

As used herein in relation to the definition of Z, a phosphonyl ester includes both the dibasic ester and the monobasic half-ester.

As used herein, 5-tetrazolyl is the group having the structural formula:



which thus embraces both tautomeric forms thereof and which are identifiable as 5-(1H)-tetrazolyl and 5-(2H)-tetrazolyl.

Included within the definition of Z is a preferred sub-class, wherein Z is carboxy, sulphonyl or phosphonyl or a C₁₋₆ alkyl ester thereof. Preferably, Z is carboxy or a C₁₋₆ alkyl, such as methyl or ethyl, ester thereof.

Most preferably, X₃ is hydrogen and X₄ is the group -Y-Z where Y is vinylene and Z is carboxy.

Preferably, both X₃ and X₄ are oxygen.

The compounds of the present invention are capable of existing as geometric and optical isomer. All such isomers, individually and as mixtures, are included within the scope of the present invention. Compounds in the form of the E-geometrical isomers, are particularly preferred.

Of the compounds exemplified hereinafter, those that are preferred include

1. (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

2. (E)-4-(1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-1-propyl-9H-purin-8-yl)cinnamic acid.

3. (E)-4-(1,3-diethyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

4. (E)-4-(1,3-diallyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

5. (E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)cinnamic acid,

6. (E)-4-(1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

7. (E)-4-(3-ethyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

8. (E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid,

9. (E)-4-(1,2,3,6-tetrahydro-3-isobutyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

10. (E)-4-(1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid,

11. (E)-4-(1,2,3,6-tetrahydro-3-isobutyl-1-

methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

12. (E)-4-(1-ethyl-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

13. (E)-4-(1,3-dibutyl-1,2,3,6-tetrahydro-1,6-dioxo-9H-purin-8-yl)cinnamic acid,

14. (E)-4-(1,3-dibenzyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

15. (E)-4-(3-butyl-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

16. (E)-4-(1-butyl-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

17. (E)-4-(3-benzyl-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

18. (E)-4-(1,2,3,6-tetrahydro-1,3-diisobutyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

19. (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-6-oxo-2-thio-9H-purin-8-yl)cinnamic acid,

20. (E)-4-[3-(4-cyanobenzyl)-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl]cinnamic acid,

21. (E)-4-[3-(3-cyanobenzyl)-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl]cinnamic acid,

22. 3-[4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)phenyl]propionic acid

23. (E)-4-[1-(4-cyanobenzyl)-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl]cinnamic acid,

24. (E)-4-(1-benzyl-1,2,3,6-tetrahydro-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid,

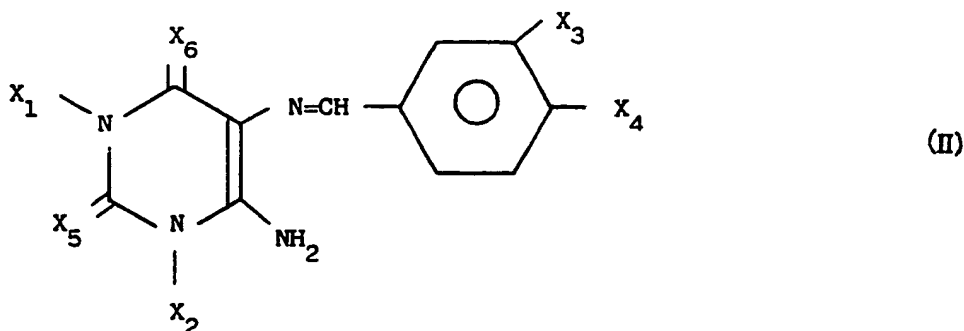
25. (E)-4-(3-benzyl-1,2,3,6-tetrahydro-2,6-dioxo-1-propyl-9H-purin-8-yl)cinnamic acid.

Compounds 13, 14, 24 and 25 are particularly preferred.

As salts of a compound of formula (I), there are included acid addition salts of the compound, wherein one of X_3 and X_4 is amino, and salts comprising the compound, wherein one of X_3 and X_4 is carboxy, or wherein the other is a group -Y-Z where Y is as hereinbefore defined and Z is carboxy, sulphonyl or phosphonyl, as an anionic species, together with a cation. In both types of salts, the pharmacological activity resides in the moiety derived from the compound of the invention as defined herein and the identity of the other component is of less importance although for therapeutic purposes it is, preferably, pharmaceutically acceptable to the recipient of the salt. Examples of pharmaceutically acceptable acid addition salts include those derived from mineral acids, such as hydrochloric, hydrobromic, phosphoric, metaphosphoric, nitric and sulphuric acids, and organic acids, such as tartaric, acetic, citric, malic, lactic, fumaric, benzoic, glycollic, gluconic, succinic and arylsulphonic, for example p-toluenesulphonic acids. Examples of salts comprising the compound, wherein one of X_3 and X_4 is carboxy, or wherein the other is a group -Y-Z where Y is as hereinbefore defined and Z is carboxy, sulphonyl or phosphonyl, as an anionic species, together with a cation, include ammonium salts, alkali metal salts, such as sodium and potassium salts, alkaline earth salts, such as magnesium and calcium salts, and salts formed with organic bases, for example, amino salts derived from mono-, di- or tri-(lower alkyl) or -(lower alkanol)amines, such as triethanolamine and diethylaminoethylamine, and salts with heterocyclic amines such as piperidine, pyridine, piperazine and morphine. The pharmaceutically acceptable salts together with the salts which are not thus acceptable have utility in the isolation and/or the purification of the compounds of the invention, and the unacceptable salts are also useful in being convertible to the acceptable salts by techniques well known the art.

Examples of a solvate of a compound of formula (I) or a salt thereof include an hydrate, for example the monohydrate.

The compounds of the present invention and the salts and solvates thereof may be prepared by any suitable process. In this regard, the present invention provides a first process for the preparation of a compound of formula (I), as defined hereinbefore, or a salt or solvate thereof, which comprises cyclising, in the presence of an oxidant, a compound of formula (II):



wherein X_1 to X_6 are as defined hereinbefore; optionally converting X_1 or X_5 or X_6 or X_2 in the resulting compound of formula (I) into another X_1 or X_5 or X_6 or X_2 respectively; in the case where one or both of X_5 and X_6 is/are oxygen, optionally converting one or both of X_5 and X_6 into sulphur; and optionally forming a salt or solvate thereof.

The cyclisation, in the presence of an oxidant, of a compound of Formula (II) may be carried out conventionally, for example, at an ambient or elevated temperature in a solvent, such as nitrobenzene.

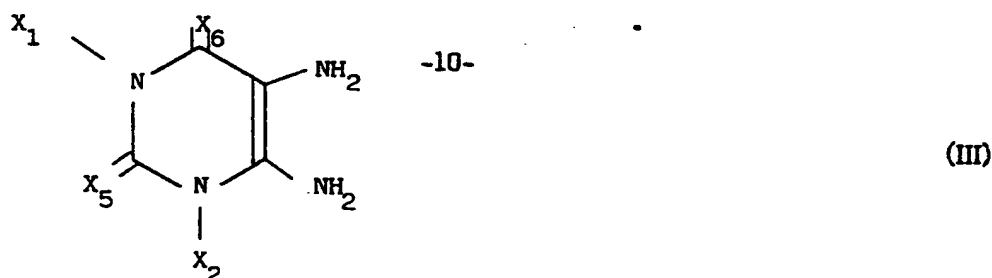
Examples of an oxidant for use in the cyclisation of a compound of formula (II) include nitrobenzene, oxygen with or without a palladium/carbon catalyst, or ferric chloride. Of these, nitrobenzene is preferred since it can also function as the solvent in which cyclisation may be carried out.

Examples of the optional conversion of X_1 or X_6 in the resulting compound of formula (I) into another X_1 or X_6 respectively are generally known in the art. One useful example is the optional conversion by reduction of 4-nitrobenzyl (for X_6) into 4-aminobenzyl. A preferred reducing agent for such reduction is hydrogen and platinum or platinum on charcoal.

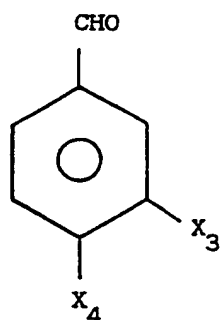
Examples of the optional conversion of X_5 or X_6 in the resulting compound of formula (I) into another X_5 or X_6 respectively are generally known in the art. One useful example is the optional conversion by hydrolysis of the group -Y-Z where Y is as hereinbefore defined and Z is a C_{1-9} alkyl, a C_{7-12} aralkyl or a C_{8-12} aryl carboxylic ester, a C_{1-9} alkyl, a C_{7-12} aralkyl or a C_{8-12} aryl sulphonyl ester, or a C_{1-9} alkyl, a C_{7-12} aralkyl or a C_{8-12} aryl phosphonyl ester into the group -Y-Z where Y is as hereinbefore defined and Z is carboxy, sulphonyl or phosphonyl respectively. Such hydrolysis may be carried out conventionally, for example, by using, in the case of a carboxylic or sulphonyl ester, aqueous sodium hydroxide or, in the case of a phosphonyl ester, concentrated hydrochloric acid and glacial acetic acid. In the case where one or both of X_5 and X_6 is/are oxygen, the optional conversion of one or both of X_5 and X_6 into sulphur may be carried out with phosphorus pentasulphide (*J. Org. Chem.*, 1977, 42, 2470).

The optional formation of a salt or solvate of a compound of formula (I) may be carried out using techniques well known in the art.

The compound of formula (II) may be prepared by reacting a compound of formula (III):



wherein X_1 and X_2 and X_5 and X_6 are as defined hereinbefore, with a compound of formula (IV):



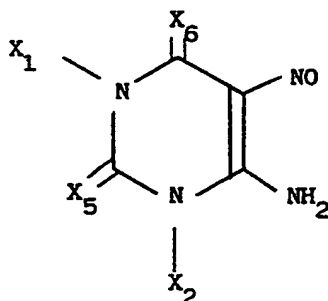
(IV)

wherein X_3 and X_4 are as defined hereinbefore.

The reaction between the compounds of formulae (III) and (IV) may be carried out conventionally, for example, by heating under reflux in a solvent, such as a mixture of acetic acid and methanol. It is, however, a preferred aspect of this process of the present invention that the resulting Schiff's base is not isolated but that the two stages leading to the compound of the present invention -

the reaction between the compounds of formulae (III) and (IV) and the cyclisation of the resulting compound of formula (II) - are carried out in one operation in the same reaction vessel. In these circumstances, the reaction between the compounds of formulae (III) and (IV) is, preferably, carried out under reflux in nitrobenzene.

The compound of formula (III) may be prepared by reducing a compound of formula (V):

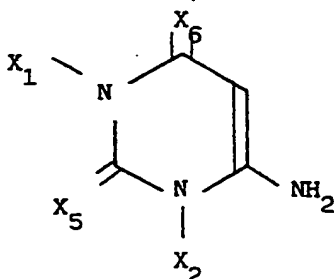


(V)

wherein X_1 and X_2 and X_5 and X_6 are as defined hereinbefore.

The reduction of the compound of formula (V) is, preferably, carried out with ammonium sulphide in the manner as described in U.S. Patent 2 602 795.

The compound of formula (V) may be prepared by reacting a compound of formula (VI):



(VI)

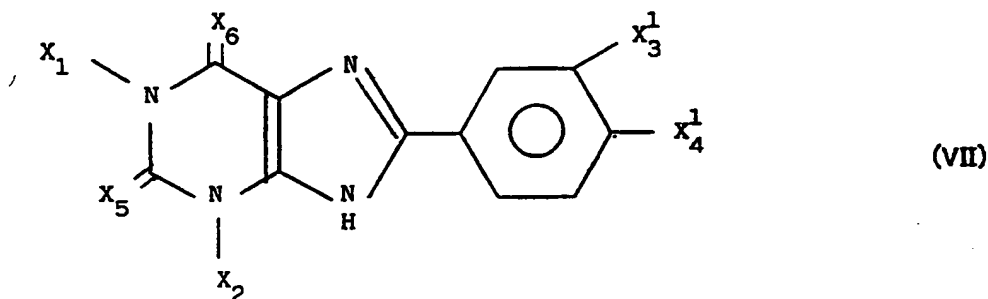
wherein X_1 and X_2 and X_3 and X_4 are as defined hereinbefore, with nitrous acid; and optionally converting X_1 or X_2 into another X_1 or X_2 as defined herein.

The reaction between the compound of formula (VI) and nitrous acid (which may be prepared *in situ* from sodium nitrite and glacial acetic acid) is, preferably, carried out in accordance with the procedure described in *J. Org. Chem.*, 1951, **16**, page 1879 *et seq.*

Examples of the optional conversion of X_1 or X_2 into another X_1 or X_2 include the optional conversion of hydrogen into C_{1-6} alkyl, C_{2-6} alkenyl or C_{7-12} aralkyl optionally substituted in the aryl ring by

C_{1-6} alkyl, C_{1-6} alkoxy, hydroxy, halo, nitro, amino, azido or cyano. In fact, if it is desired to prepare a compound of formula (I), wherein X_1 is a bulkier group than X_2 , then it is preferred first to prepare the compound of formula (VI), wherein X_1 is hydrogen, and then to convert the hydrogen atom into the desired group for X_1 .

The present invention also provides a second process for the preparation of a compound of formula (I), wherein the other of X_3 and X_4 is the group -Y-Z where Y is C_{3-6} alkenyleneoxy and Z is as hereinbefore defined, or a salt or solvate thereof, which comprises reacting a compound of formula -



wherein X_1 and X_2 and X_3 and X_4 are as hereinbefore defined and one of X_3' and X_4' is as defined hereinbefore for one of X_3 and X_4 and the other is hydroxy, with a compound of formula (VIII);

L-Y-Z (VIII)

wherein L is a leaving group, Y' is C_{3-6} alkenylene and Z is as hereinbefore defined; optionally converting X_1 or X_2 or X_3 or X_4 in the resulting compound of formula (I) into another X_1 or X_2 or X_3 or X_4 respectively; in the case where one or both of X_3 and X_4 is/are oxygen, optionally converting one or both of X_3 and X_4 into sulphur; and optionally forming a salt or solvate thereof.

The reaction between the compounds of formulae (VII) and (VIII) may be carried out conventionally, for example, in the presence of a base, such as an alkali metal alkoxide, in particular potassium *t*-butoxide, in a solvent, such as dimethyl sulphoxide, under an inert atmosphere. A preferred example of the leaving group (L) is bromo.

Examples of the optional conversion of X_1 or X_2 in the resulting compound of formula (I) into another X_1 or X_2 respectively are as described hereinbefore in relation to the corresponding optional conversions carried out on the compound of formula (I) resulting from the cyclisation of a compound of formula (II).

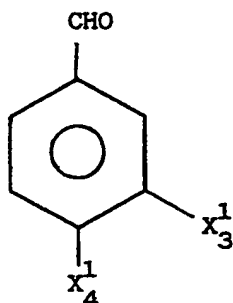
Examples of the optional conversion of X_3 or X_4 in the resulting compound of formula (I) into another X_3 or X_4 respectively are generally known in the art. An example is the optional conversion by hydrolysis of the group -Y-Z where Y is C_{3-6} alkenyleneoxy and Z is a C_{1-6} alkyl, a C_{7-12} aralkyl or a C_{6-12} aryl carboxylic ester, a C_{1-6} alkyl, a C_{7-12} aralkyl or a C_{6-12} aryl sulphonyl ester or a C_{1-6} alkyl, a C_{7-12} aralkyl or a C_{6-12} aryl phosphonyl ester into the group -Y-Z where Y is C_{3-6} alkenyleneoxy and Z is carboxy, sulphonyl or phosphonyl. Such hydrolysis may be carried out as described hereinbefore.

In the case where one or both of X_3 and X_4 is/are oxygen, the optional conversion of one or both of X_3 and X_4 into sulphur may be carried out as described hereinbefore.

The optional formation of a salt or solvate of a compound of formula (I) may be carried out using techniques well known in the art.

It should be noted that, during the reaction between the compounds of formulae (VII) and (VIII), a side-reaction may occur at the nitrogen atom in the 7-position in the compound of formula (VII). It will, therefore, be appreciated that the reagents and conditions should be chosen so as to minimise the occurrence of any such side-reaction. In any case,

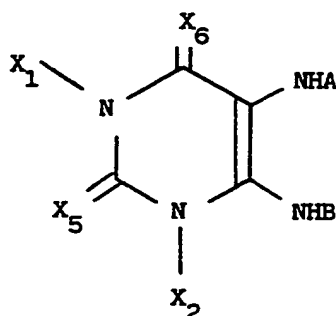
it is preferred, for reasons of a better yield and a cleaner product, that the preparation of a compound of formula (I), wherein the other of X_3 and X_4 is the group $-Y-Z$ where Y is C_{3-8} alkenyleneoxy and Z is as hereinbefore defined, is carried out using the first process of the invention involving the cyclisation of a compound of formula (II).



(IX)

wherein X_3^1 and X_4^1 are as hereinbefore defined.

The reaction between the compounds of formulae (III) and (IX) may be carried out analogously to the reaction between the compounds of formulae (III) and (IV) as described hereinbefore.



(X)

wherein X_1 and X_2 and X_5 and X_6 are as defined hereinbefore and one of A and B is hydrogen and the other is 3-(X_3)-4-(X_4)-benzoyl in which X_3 and X_4 are as defined hereinbefore; optionally converting X_1 or X_2 or X_5 or X_6 in the resulting compound of formula (I) into another X_1 or X_2 or X_5 or X_6 respectively; in the case where one or both of X_5 and X_6 is/are oxygen, optionally converting one or both of X_5 and X_6 into sulphur; and optionally forming a salt or solvate thereof.

The cyclisation of a compound of formula (X) may be carried out conventionally. For example, in the case where B is hydrogen and A is 3-(X_3)-4-(X_4)-benzoyl, the cyclisation is, preferably, carried out in the presence of aqueous base, such as aqueous sodium hydroxide, at elevated tempera-

The compound of formula (VII) may be prepared by reacting a compound of formula (III), as defined hereinbefore, with a compound of formula - (IX):

The present invention also provides a third process for the preparation of a compound of formula (I), as defined hereinbefore, or a salt or solvate thereof, which comprises cyclising a compound of formula (X):

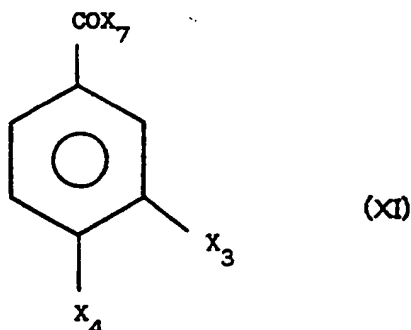
ture, and, in the case where A is hydrogen and B is 3-(X_3)-4-(X_4)-benzoyl, the cyclisation usually proceeds spontaneously in view of the highly nucleophilic 5-amino substituent.

Examples of the optional conversion of X_1 or X_2 or X_5 or X_6 in the resulting compound of formula (I) into another X_1 or X_2 or X_5 or X_6 respectively are as described hereinbefore in relation to the corresponding optional conversions carried out on the compound of formula (I) resulting from the cyclisation of a compound of formula (II).

In the case where one or both of X_5 and X_6 is/are oxygen, the optional conversion of one or both of X_5 and X_6 into sulphur may be carried out as described hereinbefore.

The optional formation of a salt or solvate of a compound of formula (I) may be carried out as described hereinbefore. In this regard, it should be noted that, if the cyclisation of a compound of formula (X) is carried out in the presence of aqueous base, then the compound of formula (I) is normally obtained as the salt. The free acid of formula (I) can be regenerated simply by treatment of the salt with acid.

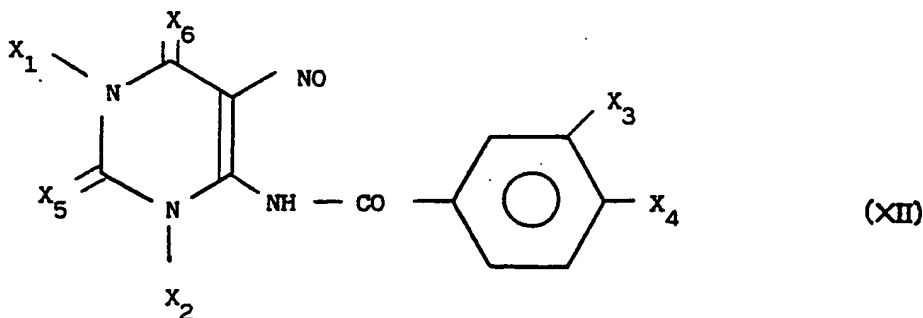
The compound of formula (X), wherein B is hydrogen and A is 3-(X₃)-4-(X₄)-benzoyl, may be prepared by reacting a compound of formula (III), as defined hereinbefore, with a compound of formula (XI):



wherein X₃ and X₄ are as defined hereinbefore and X₇ is hydroxy, chloro, bromo or C₁₋₆ alkylcarbonyloxy.

The compound of formula (X), wherein A is hydrogen and B is 3-(X₃)-4-(X₄)-benzoyl, may be prepared by reducing a compound of formula (XII):

The reaction between the compounds of formulae (III) and (XI) may be carried out conventionally. For example, in the case where X₇ is hydroxy, the reaction may be carried out in the presence of a condensation promoting agent, such as dicyclohexylcarbodiimide.



wherein X₁ to X₆ are as defined hereinbefore.

The reduction of a compound of formula (XII) may be carried out conventionally, for example, by catalytic hydrogenation with Raney nickel or platinum or by using ammonia sulphide as described in U.S. Patent 2 602 795. As mentioned previously, the 5-amino substituent of the resulting compound of formula (X), wherein A is hydrogen and B is 3-

(X₃)-4-(X₄)-benzoyl, is highly nucleophilic with the result that the compound of formula (X) normally proceeds spontaneously to the desired compound of formula (I).

The compound of formula (XII) may be prepared by reacting a compound of formula (V), as defined hereinbefore, with a compound of formula (XI), as defined hereinbefore.

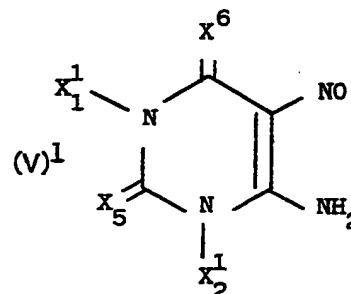
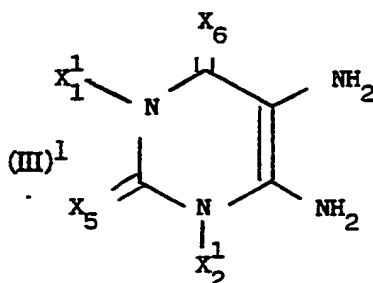
The reaction between the compounds of formulae (V) and (XI) may be carried out analogously to the reaction between the compounds of formulae (III) and (XI) described hereinbefore.

It should be noted that, if, in the reactions between the compounds of formulae (III) and (XI) and of formulae (V) and (XI), the other of X_5 and X_6 in formula (XI) is the group $-Y-Z$ where Y is as defined hereinbefore and Z is carboxy, sulphonyl or phosphonyl, then the reagents and conditions should be chosen so as to minimise the occurrence of any competing side-reaction at the acidic group for Z and to maximise the desired reaction between the carboxy group or derivative thereof (COX_6) depicted in formula (XI) and the amino substituent in the 5-position in the compound of formula (III). Alternatively, the acidic group for Z may be blocked during the course of the reaction and then deblocked after its completion. Examples

of preferred blocked acidic groups include C_{1-6} alkyl esters, C_{7-12} aralkyl esters or C_{6-12} aryl esters, the blocking groups of which may be added to and removed from the acidic group in conventional manner. Because of the need to avoid a competing side-reaction either by the employment of particular reagents and conditions or by using a blocked acidic group, this process of the invention is generally the least preferred.

The compounds of formulae (II), (X) and (XII) and a number of the compounds of formulae (III), (V) and (VII), as described hereinafter, are novel intermediates of use in the preparation of the compounds of formula (I) and, thus, represent part of the present invention.

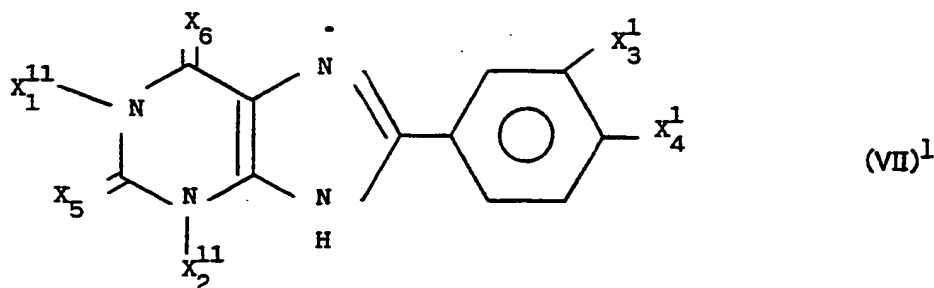
The compounds of formulae (III) and (V) that are novel intermediates are of formulae (III)¹ and (V)¹:



wherein X_{11} is methyl and X_5 is propyl, X_{11} is propyl and X_5 is methyl, X_{11} is *n*-butyl and X_5 is methyl, X_{11} and X_5 are both *iso*-butyl, X_{11} and X_5 are both allyl, or X_{11} and X_5 are the same or

different and are C_{7-12} aralkyl optionally substituted in the aryl ring by C_{1-6} alkyl, C_{1-6} alkoxy, hydroxy, halo, nitro, amino, azido or cyano.

The compounds of formula (VII) that are novel intermediates are of formula (VII)¹:



wherein X_{11} and X_5 are the same or different and are hydrogen, C_{2-6} alkyl, C_{2-6} alkenyl or C_{7-12} aralkyl optionally substituted in the aryl ring by C_{1-6}

alkyl, C_{1-6} alkoxy, hydroxy, halo, nitro, amino, azido or cyano, and X_3 and X_4 are as defined hereinbefore.

The compounds of formulae (IV), (VI), (VIII), - (IX) and (XI) are commercially available, or may be obtained by carrying out a published process for their preparation, or by carrying out a process analogous to a published process for the preparation of structurally analogous compounds. For example, the compounds of formula (IV), wherein the other of X_1 and X_2 is the group -Y-Z where Y is C_{3-6} alkenyleneoxy and Z is as hereinbefore defined, may be obtained by alkenylating in a conventional manner the corresponding hydroxybenzaldehyde.

While it is possible for the compounds of the present invention and the salts and solvates thereof to be administered as the raw chemical, it is preferred to present them in the form of a pharmaceutical formulation. Accordingly, the present invention further provides a pharmaceutical formulation, for human or veterinary application, which comprises a compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, and a pharmaceutically acceptable carrier therefor.

The pharmaceutical formulation may optionally contain other therapeutic agents that may usefully be employed in conjunction with the compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof. The expression "pharmaceutically acceptable" as used herein in relation to the carrier is used in the sense of being compatible with the compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, employed in the formulation and with any other therapeutic agent that may be present, and not being detrimental to the recipient thereof. The carrier itself may constitute one or more excipients conventionally used in the art of pharmacy that enable the compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, and any other therapeutic agent that may be present, to be formulated as a pharmaceutical formulation.

The pharmaceutical formulations of the present invention include those suitable for oral, parenteral (including subcutaneous, intradermal, intramuscular and intravenous) and rectal administration although the most suitable route will probably depend upon, for example, the precise nature and severity of the condition and the identity of the recipient. The formulations may conveniently be presented in unit dosage form and may be prepared by any of the methods well known in the art of pharmacy. All methods include the step of bringing into association the active ingredient, i.e. the compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, with the carrier. In general the formulations are prepared by uniformly and

intimately bringing into association the active ingredient with, a liquid carrier or, a finely divided solid carrier or both, and then, if necessary, forming the associated mixture into the desired formulation.

The pharmaceutical formulations of the present invention suitable for oral administration may be presented as discrete units, such as a capsule, cachet tablet, or lozenge, each containing a predetermined amount of the active ingredient; as a powder or granules; as a solution or a suspension in an aqueous liquid or a non-aqueous liquid such as a syrup, elixir or a draught; or as an oil-in-water liquid emulsion or a water-in-oil liquid emulsion. The formulation may also be a bolus, electuary or paste.

Generally, a tablet is the most convenient pharmaceutical formulation suitable for oral administration. A tablet may be made by compressing or moulding the tablets may be prepared by compressing in a suitable machine the active ingredient in a free-flowing form, such as a powder or granules, in admixture with, for example, a binding agent, an inert diluent, a lubricating agent, a disintegrating agent and/or a surface active agent. Moulded tablets may be prepared by moulding in a suitable machine a mixture of the powdered active ingredient moistened with an inert liquid diluent. The tablets may optionally be coated or scored and may be formulated so as to provide slow or controlled release of the active ingredient.

The pharmaceutical formulations of the present invention suitable for parenteral administration include aqueous and non-aqueous sterile injection solutions which may contain, for example, an antioxidant, a buffer, a bacteriostat and a solute which renders the composition isotonic with the blood of the recipient, and aqueous and non-aqueous sterile suspensions which may contain, for example, a suspending agent and a thickening agent. The formulations may be presented in unit-dose or multi-dose containers, for example sealed ampoules and vials, and may be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid carrier, for example water for injection, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets of the kind previously described.

The pharmaceutical formulations of the present invention suitable for rectal administration may be presented as a suppository containing, for example, cocoa butter and polyethylene glycol.

An advantage of the compounds of the present invention and the pharmaceutically acceptable salts and solvates thereof is that they are generally water soluble and that, therefore, they are suitable

for formulation as aqueous solutions. In contrast, a number of the various substituted 8-phenylxanthines of the prior art (Biochem. Pharmac., 1981, 30, 325 to 353; and Proc. Nat. Acad. Sci., 1983, 80, 2077 to 2080) are not soluble in water or at least not sufficiently soluble so as to permit their formulation in this way.

As mentioned hereinbefore, the compounds of the present invention and the pharmaceutically acceptable salts and solvates thereof are of use in human and veterinary medicine and in particular in the treatment or prophylaxis of pathophysiological disorders arising from the cell surface effects of adenosine. Accordingly, the present invention yet further provides a method for the treatment or prophylaxis of an animal with a pathophysiological disorder arising from the cell surface effects of adenosine, which comprises administering to the animal a therapeutically or prophylactically effective amount of a compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof. In the alternative, there is also provided a compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, for use in human or veterinary medicine and in particular for use in the treatment or prophylaxis of pathophysiological disorders arising from the cell surface effects of adenosine.

The pathophysiological disorders caused by adenosine/cell-surface interactions and requiring treatment or prophylaxis in accordance with the present invention generally arise within the cardiovascular, gastrointestinal or neuroendocrine systems since adenosine has a particularly pronounced effect on the cell surface receptors in these systems and hence on their physiology. Particular examples of such pathophysiological disorders include heart block induced by various diagnostic procedures, such as scintigraphy, or occurring as a result of a myocardial infarct where there is increased leakage of endogenous adenosine into the extracellular environment surrounding the heart muscle (Cir. Res., 1982, 51, 569 et seq.). Other examples of such conditions include asthma and irritable bowel syndrome.

The animal requiring treatment or prophylaxis with a compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, is usually a human or non-human mammal.

The route by which the compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, is administered to the animal may be oral, parenteral (including subcutaneous, intradermal, intramuscular, intravenous or rectal). If the compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof,

is presented in the form of a pharmaceutical formulation, which, as mentioned hereinbefore, is preferred, then the actual formulation employed will of course depend on the route of administration elected by the physician or veterinarian. For example, if oral administration is preferred, then the pharmaceutical formulation employed is, preferably, one which is suitable for such a route.

A therapeutically or prophylactically effective amount of a compound of the present invention, or a pharmaceutically acceptable salt or solvate thereof, will depend upon a number of factors including, for example, the age and weight of the animal, the precise condition requiring treatment or prophylaxis and its severity, and the route of administration, and will ultimately be at the discretion of the attendant physician or veterinarian. However, an effective amount of a compound of the present invention for the treatment or prophylaxis of pathophysiological disorders arising from the cell surface effects of adenosine, will generally be in the range of 0.1 to 50 mg/kg body weight of recipient per day, more usually in the range of 0.5 to 10mg/kg body weight per day and most often in the range of 1 to 5 mg/kg body weight per day. Thus, for a 70kg adult patient, the actual amount per day would most often be from 70 to 350mg and this amount may be given in a single dose per day or more usually in a number (such as two, three or four) of sub-doses per day such that the total daily dose is the same.

An effective amount of a pharmaceutically acceptable salt or solvate of a compound of the present invention may be determined as a proportion of the effective amount of the compound per se.

The compounds of the present invention and the salts and solvates thereof may also be used, in a manner known generally in the art, in the isolation and purification of adenosine receptors.

The following examples and pharmacological data are provided in illustration of the present invention and should not be construed as in any way constituting a limitation thereof.

EXAMPLE 1: Preparation of (E)-4-(1,2,3,8-tetrahydro-1,3-dimethyl-2,6-dioxo-9H-purin-8-yl)-cinnamic acid

5,6-Diamino-1,3-dimethyluracil hydrate (1.70 g, 10.0 mmol) and 4-formylcinnamic acid (1.76 g, 10.0 mmol) were refluxed in acetic acid (10 mL)-methanol (100 mL) for 0.5 hour. (E)-4-[(6-Amino-1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinyl)-iminomethyl]cinnamic acid was precipitated as yet-

low powder (1.84 g, 56%); mp 299-301°C with effervescence. Analysis for (C₁₈H₁₈N₄O₄): C, 58.53; H, 4.91; N, 17.07. Found: C, 58.36; H, 4.93; N, 16.90. Structure confirmed by ¹H-NMR and FI mass spectrum.

(E)-4-[(6-Amino-1,2,3,4-tetrahydro-1,3-dimethyl-2,4-dioxo-5-pyrimidinylmethyl)cinnaic acid (500 mg, 1.52 mmol) was refluxed in nitrobenzene (125 mL) for 2.5 hours with slow distillation to remove water formed. The reaction mixture was cooled and the precipitate washed with ether. Recrystallization from N,N-dimethylformamide-water gave the monohydrate of the title compound as a pale yellow powder; mp>380°C. Analysis for (C₂₂H₂₄N₄O₆·H₂O): C, 55.81; H, 4.68; N, 16.27. Found: C, 56.05; H, 4.69; N, 16.27. Structure confirmed by ¹H-NMR and EI mass spectrum.

EXAMPLE 2: Preparation of (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-2,6-dioxo-9H-purin-8-yl)cinnaic acid

5,6-Diamino-1,3-dimethyluracil hydrate (5.11 g, 30.0 mmol) and 4-formylcinnaic acid (5.29g, 30.0 mmol) were refluxed in nitrobenzene (500 mL). The nitrobenzene was allowed to distill slowly with water formed. Fresh nitrobenzene was added to keep the volume constant. After 5 hours of reflux, the mixture was cooled and the precipitate collected (8.07 g). Recrystallization from N,N-dimethylformamide-water gave the monohydrate of the title compound as a pale yellow powder, identical with that of Example 1 by ¹H-NMR and elemental analysis.

EXAMPLE 3: Preparation of (E)-4-(1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-1-propyl-9H-purin-8-yl)cinnaic acid

6-Amino-1-methyl-3-propyl-2,4-(1H,3H)-pyrimidinedione (V. Papesch and E.F. Schroeder, J.Org.Chem. 1951, 16, 1879) (5.53g, 27.5mmol) was dissolved in hot 95% ethanol (20ml)-water (120ml). Sodium nitrite (2.32g) and glacial acetic acid (2.4ml) were added. The resulting mixture was allowed to cool to room temperature. Orange-pink crystals were filtered off and dried at 50°C under vacuum to give purple crystals of 6-amino-1-methyl-5-nitroso-3-propyl-2,4-(1H,3H)-pyrimidinedione (2.92g, 80%); mp 250°dec. Analysis for (C₁₈H₁₈N₄O₄): C,45.28; H,5.70; N,26.40. Found: C,45.12; H,5.74; N,26.34.

5,6-Diamino-1-methyl-3-propyl-2,4-(1H,3H)-pyrimidinedione was prepared freshly from 6-

amino-1-methyl-5-nitroso-3-propyl-2,4-(1H,3H)pyrimidinedione by ammonium sulfide reduction using the method of V. Papesch, M. Grove, and F.F. Schroeder (U.S. Patent 2 602 795). This diamine (2.00g, 10.0mmol) was condensed with 4-formylcinnaic acid (1.76g, 10.0mmol) by the procedure of Example 2 to give the title compound as an ivory powder, after crystallization from N,N-dimethylformamide-water; mp>300°C. Analysis for (C₂₂H₂₄N₄O₆·1/5 DMF): C,60.54; H,5.30; N,15.94. Found: C,60.52; H,5.22; N,16.03.

Example 4: Preparation of (E)-4-(1,3-diethyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnaic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 360°C. Analysis for (C₂₈H₂₈N₄O₄): C,61.1; H,5.12; N,15.81. Found: C,61.04; H,5.15; N,15.81.

Example 5: Preparation of (E)-4-(1,3-diallyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnaic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point of greater than 300°C. Analysis for (C₂₈H₂₈N₄O₄): C,63.48; H,4.80; N,14.81. Found: C,63.26; H, 4.86; N,14.71.

Example 6: Preparation of (E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)cinnaic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point of 355°C (dec.). Analysis for (C₃₂H₃₂N₄O₄): C,62.82; H,5.80; N,14.65. Found: C,62.91; H,5.84; N,14.63.

Example 7: Preparation of (E)-4-(1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnaic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point of 300°C. Analysis for (C₂₂H₂₂N₄O₄): C,57.69; H,3.87; N,17.94. Found: C,57.47; H,3.90; N,17.87.

Example 8: Preparation of (E)-4-(3-ethyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnaic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₄H₂₄N₄O₄): C,58.89; H,4.32; N,17.17. Found: C,58.64; H,4.36; N,17.24.

Example 9: Preparation of (E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₂H₂₂N₄O₄): C, 59.94; H, 4.74; N, 16.46. Found: C, 59.78; H, 4.76; N, 16.41.

Example 10: Preparation of (E)-4-(1,2,3,6-tetrahydro-3-isobutyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₄H₂₄N₄O₄): C, 61.01; H, 5.12; N, 15.81. Found: C, 60.85; H, 5.17; N, 15.74.

Example 11: Preparation of (E)-4-(1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₃H₂₃N₄O₄): C, 61.01; H, 5.12; N, 15.81. Found: C, 60.86; H, 5.16; N, 15.76.

Example 12: Preparation of (E)-4-(1,2,3,6-tetrahydro-3-isobutyl-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₆H₂₆N₄O₄): C, 61.95; H, 5.47; N, 15.21. Found: C, 61.99; H, 5.51; N, 15.19.

Example 13: Preparation of (E)-4-(1-ethyl-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₇H₂₆N₄O₄): C, 60.00; H, 4.74; N, 16.46. Found: C, 59.91; H, 4.77; N, 16.43.

Example 14: Preparation of (E)-4-(1,3-dibutyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point of 350-355°C. Analysis for (C₂₈H₂₈N₄O₄): C, 64.38; H, 6.39; N, 13.65. Found: C, 64.11; H, 6.42; N, 13.57.

EXAMPLE 15: Preparation of (E)-4-(1,3-dibenzyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₃₂H₂₈N₄O₄): C, 70.28; H, 4.65; N, 11.71. Found: C, 70.04; H, 4.67; N, 11.63.

EXAMPLE 16: Preparation of (E)-4-(3-butyl-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₉H₂₈N₄O₄): C, 61.94; H, 5.47; N, 15.21. Found: C, 61.77; H, 5.52; N, 15.16.

EXAMPLE 17: Preparation of (E)-4-(1-butyl-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₉H₂₈N₄O₄): C, 61.94; H, 5.47; N, 15.21. Found: C, 61.70; H, 5.50; N, 15.11.

EXAMPLE 18: Preparation of (E)-4-(3-benzyl-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid.

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₃₂H₂₈N₄O₄): C, 65.66; H, 4.51; N, 13.92. Found: C, 65.43; H, 4.60; N, 13.87.

EXAMPLE 19: Preparation of (E)-4-(1,2,3,6-tetrahydro-1,3-diisobutyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₈H₂₈N₄O₄): C, 64.37; H, 6.39; N, 13.65. Found: C, 64.23; H, 6.42; N, 13.64.

EXAMPLE 20: Preparation of (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-6-oxo-2-thio-9H-purin-8-yl)-cinnamic acid

5,6-Diamino-1,3-dimethyl-2-thiouracil (K.R.H. Woolridge and R. Slack, *J. Chem. Soc.*, 1962, 1863) (0.93g, 5.0mmol) and 4-formylcinnamic acid (0.88g, 5.0mmol) were refluxed in nitrobenzene - (100mL) for 30 minutes with slow distillation of water formed. After cooling, the yellow solid was filtered and washed, first with ethanol then with ether, to give the title compound, m.p. >320°C. Analysis for (C₂₂H₂₂N₄O₄S): C, 56.13; H, 4.12; N, 16.35; S, 9.36; Found: C, 56.21; H, 4.15; N, 16.35; S 9.44.

EXAMPLE 21: 3-[4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl) phenyl]Propionic acid.

A suspension of (E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)cinnamic acid - (4.00g, 10.4mmol) (Example 6) and concentrated sulfuric acid (1 ml) in absolute ethanol (1.5 L) was refluxed for 2 hours with slow distillation of 75 ml of vapor. Reflux was continued for 3 days with exclusion of moisture with 50 ml distillate being removed during the final 4 hours. The cooled suspension was filtered to yield ethyl (E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)cinnamate as a pale yellow solid. mp >300°C. Analysis for (C₂₂H₂₂N₄O₄): C, 64.38; H, 6.38; N, 13.65. Found: C, 64.34; H, 6.43; N, 13.63.

A solution of bromine (1.2 g, 7.5 mmol) in glacial acetic acid (25 ml) was added over 30 minutes to a suspension of the above ethyl ester - (3.00 g, 7.31 mmol) in glacial acetic acid (125 ml) at 40°C. After stirring at room temperature overnight, the suspension was treated with bromine (0.2 ml) in glacial acetic acid (25 ml), warmed at 60°C for 3 hours, and finally treated with bromine (one drop). After cooling to room temperature, a small amount of solid was filtered off, and the filtrate was evaporated to dryness. The residue was triturated in 1:1 ethyl acetate ether (140 ml) and filtered to yield ethyl 2,3-dibromo-3-[4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-1H-purin-8-yl)phenyl]propionate as a pale yellow solid; m.p. 221.5 -223°C with effervescence.

Analysis for (C₂₂H₂₂Br₂N₄O₄): C, 46.33; H, 4.60; N, 9.82; Br, 28.02. Found: C, 46.43; H, 4.65; N, 9.77; Br, 27.97.

A suspension of the above dibromopropionate - (3.00g, 5.26 mmol) in an anhydrous ethanolic solution (150 ml) of potassium hydroxide (1.5 g 26 mmol) was refluxed for 21 hours, then diluted over

3 hours with water (250 ml) as the ethanol was allowed to evaporate. The cooled solution was treated with 1 N HCl until a precipitate formed (pH 10) which was extracted with methylene chloride - (100 ml). The aqueous phase was made strongly acidic with 1 N HCl. The thick precipitate was filtered and dried to yield a solid. A portion of this solid (0.65 g) was recrystallised from 50% ethanol - (50 ml) to give the title compound as a yellow solid as the hemihydrate; mp slow dec. starting at 260°C. Analysis for (C₂₂H₂₂N₄O₄·5 H₂O): C, 61.69; H, 5.44; N, 14.39. Found: C 61.85; H, 5.38; N, 14.45.

EXAMPLE 22: (E)-4-[3-(4-Cyanobenzyl)-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl]-cinnamic acid.

α-Amino-*p*-tolunitrile (prepared from α-bromotolunitrile in a modification of the method described by J.H. Short and T.D. Darby, *J. Med. Chem.*, 10 (5), 833, 1967) was treated first with methyl isocyanate followed by cyanoacetic acid according to the method of V. Papesch and E.F. Schroeder (*J. Org. Chem.*, 1951, 16, 1879) to yield 4-[(6-amino-1,2,3,4-tetrahydro-3-methyl-2,4-dioxo-1-pyrimidinyl)methyl]benzonitrile, which was then nitrosated, reduced, and condensed with 4-formylcinnamic acid following an analogous procedure to that of Example 3 to give the title compound as a yellow solid with a melting point greater than 350°C. Analysis for (C₂₂H₂₀N₄O₄): C, 64.63; H, 4.01; N, 16.38. Found: C, 64.58; H, 4.06; N, 16.36.

EXAMPLE 23: (E)-4-[3-(3-Cyanobenzyl)-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl]-cinnamic acid.

Following an analogous procedure to that of Example 22, the title compound was prepared with a melting point greater than 300°C. Analysis for (C₂₂H₂₀N₄O₄): C, 64.63; H, 4.01; N, 16.38. Found: C, 64.40; H, 4.04; N, 16.45.

EXAMPLE 24: (E)-4-[1-(4-Cyanobenzyl)-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl]-cinnamic acid

α-Bromo-*p*-tolunitrile (5.41 g, 27.6 mmol) was added at once with stirring to a solution of 6-amino-1-methyluracil (V. Papesch and E.F.Schroeder, *J. Org. Chem.* (1951), 16, 1879) (3.90 g, 27.6 mmol) in 1:1 ethanol: 1 N sodium hydroxide (56 ml) at 42°C. After 1.75 hours, the mixture was cooled, filtered and washed with water. The resulting solid and second crop obtained by vaporation of the filtrate were combined (5.80 g) and partially purified

by silica gel chromatography followed by repeated trituration with 1:2 methanol; ether to give crude 4-[(6-Amino-1,2,3,4-tetrahydro-1-methyl-2,4-dioxo-3-pyrimidinyl)methyl]benzonitrile (0.86 g), identified by NMR.

To a refluxing solution of this solid (0.17 g, 0.60 mmol) in 2:1:1 H₂O: ethanol: glacial acetic acid (12 ml) was added a solution of sodium nitrite - (0.063 g, 0.91 mmol) in water (0.5 ml). After refluxing for one minute, the mixture was cooled with stirring, then filtered to give 4-[(6-amino-1,2,3,6-tetrahydro-1-methyl-5-nitroso-2,4-dioxo-3-pyrimidinyl)methyl] benzonitrile as a purple solid - (0.17 g, 77%); m.p. 266°(dec). Analysis for (C₁₂H₁₁N₅O₃): C, 54.74; H, 3.89; N, 24.55. Found: C, 54.80; H, 3.91; N, 24.49.

This intermediate (0.50 g, 1.7 mmol) was reduced to the dianine with ammonium sulfate according to the method of V. Papesch, H. Grove, and E.F. Schroeder, U.S. Patent 2,602,795. The resulting solid (0.47 g) was directly combined with 4-formylcinnamic acid (0.21 g, 1.2 mmol) and refluxed in nitrobenzene (40 ml) for 30 minutes with distillation of nitrobenzene and water formed (total volume 12 ml). The cooled mixture was filtered and washed with ethanol to give the title compound as a pale yellow solid: m.p. >300°C. Analysis for - (C₂₂H₁₇N₅O₄ · 0.25 H₂O): C, 63.95; H, 4.05; N, 16.21. Found: C, 64.05; H, 4.09; N, 16.20.

Example 25: (E)-4-(1-Benzyl-1,2,3,6-tetrahydro-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid.

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for - (C₂₈H₂₂N₄O₄): C, 66.97; H, 5.15; N, 13.02. Found: C, 67.07; H, 5.19; N, 13.02.

Example 26: (E)-4-(3-Benzyl-1,2,3,6-tetrahydro-2,6-dioxo-1-propyl-9H-purin-8-yl)cinnamic acid.

Following an analogous procedure to that of Example 3, the title compound was prepared with a melting point greater than 300°C. Analysis for - (C₂₈H₂₂N₄O₄): C, 66.97; H, 5.15; N, 13.02. Found: C, 66.80; H, 5.16; N, 13.01.

Example 27: Cardiac Effects

The ability of (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid to inhibit ADO-induced prolongation of the atrio-to-His bundle conduction time and, thus, its potential for the treatment of cardiac disorders including heart block, was evaluated in isolated, perfused guinea-pig heart preparations.

Male and female guinea-pigs were sacrificed by a blow to the head, and their hearts were quickly removed. The heart was then hung on a retro-grade aortic infusion apparatus. Physiological Krebs-Henseleit solution (in mM; sodium chloride, 120.0, potassium chloride, 4.8, calcium chloride, 2.5, magnesium sulfate, 1.2, potassium phosphate, 1.2, pyruvic acid, 2.0, glucose, 5.5, sodium bicarbonate, 25.0, disodium EDTA 0.6, ascorbic acid, 0.3) at pH 7.4, 34.5-35.5°, gassed with 95% oxygen, 5% nitrogen, was the infusion medium. The right atrial appendage and wall containing the sinoatrial pacemaker was then removed. The pulmonary artery and the mitral valve were cut. The stimulating electrode was placed on the left atrial appendage. Electrodes were appropriately placed to permit recording of the left atrial (LAE) and His-Bundle (HBE) electrograms. Stimulus delay and duration were usually two milliseconds. The voltage was set at two times threshold, or about 6-9 volts. A Grass S4 stimulator was used for stimulation.

Pacing was initiated at a rate that ensured one to one capture and later was set to 2-3 Hz. Control atria-His Bundle times (A-H intervals) were obtained once the heart had stabilized. Adenosine infusion (5.0 μm, mixed in Henseleit-Krebs solution) was then begun for a period of five minutes. Atrio-ventricular block frequently occurred at pacing frequencies of 3 Hz, so the pacing in these cases was lowered to a rate where one-to-on conduction was seen. This rate was in the range of 1.5-2.5 Hz. Once the A-H interval had stabilized, a recording for maximum ADO effect was obtained. Infusion of varying doses of antagonist concurrent with the 5 μm ADO infusion was then begun. A Razel A-99 syringe pump was used to infuse the antagonist into the perfusate line. The antagonists were made up in 1.0 mM potassium phosphate buffer, pH 7.4, at a stock concentration of 0.2 mM. Final infusion concentration levels of the antagonists were in a range of 0.20-30.0 μm. The antagonists were infused at a given concentration for three minutes before electrogram recordings were obtained. Two antagonists were evaluated per guinea-pig. A wash period of ten minutes between antagonists was done.

A.V. conduction times were measured from the HBE and LAE. The AH interval was defined as the time between the beginning of the stimulus artifact and at the beginning of the His bundle spike, i.e., S-H interval. Measurements were compiled for control (no ADO or antagonist), ADO (no antagonist), and ADO plus antagonist (A-A) concentrations. Differences were then calculated by subtracting the control interval in question. Percentage ADO prolongation inhibition (%INH) was calculated by subtracting the A-A difference from the ADO difference, dividing by ADO difference, and multiplying by 100, thus $\%INH = (ADO \text{ diff.} - \text{ant. diff.}) / ADO \text{ diff.}$

*100.

The $K_d(50)$ was then evaluated by an Eadie-Scatchard plot, where $(\%INH)/(\text{antagonist conc.})$ was plotted on the ordinate and %INH on the abscissa. $K_d(50)$ was provided by the negative reciprocal of the slope. The mean $K_d(50)$ for (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid for five animals was found to be $0.19 \mu\text{m}$.

Example 28: Injection Formulation

<u>Ingredient</u>	<u>Amount per Ampoule</u>
Compound of the Invention	10.0mg
Buffering Agent, q.s.	-
Water, q.s.	1.0ml

The compound of the invention is finely ground and dissolved in the water. The pH is adjusted to the proper value by the buffering agent, and the solution is filtered and sterilised by autoclaving before being sealed under sterile conditions in ampoules.

Example 29: Suppository Formulation

<u>Ingredient</u>	<u>Amount per Ampoule</u>
Compound of the invention	75.0mg
Cocoa Butter	2.0g
or Wecobee TM Base	

(Wecobee is a trademark and is a hydrogenated fatty carboxylic acid).

The compound of the invention is finely ground and mixed with the melted Cocoa Butter or WecobeeTM base. It is then poured into moulds and allowed to cool to afford the suppositories.

Example 30: Syrup Formulation

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<u>Ingredient</u>	<u>Amount per 5ml</u>	
Compound of the Invention	35.0mg	
Sucrose		2.0mg
Methylparaben		0.5mg
Sodium Benzoate	0.5mg	
Cherry Flavour		q.s.
Colouring		q.s.
Water		q.s. to 5.0ml

Ethanol, sucrose, sodium benzoate, methylparaben, and flavouring are combined in 70% of the total batch quantity of water. Colouring and the compound of the invention are then dissolved in the remaining water, and finally the two solutions are mixed and clarified by filtration, thus affording a syrup.

Example 31: Tablet Formulation

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<u>Ingredient</u>	<u>Amount per Tablet</u>	
Compound of the Invention	75.0mg	
Lactose		110.0mg
Corn Stach, Pregelatinized	2.5mg	
Potato Starch		12.0mg
Magnesium stearate		0.5mg

The compound of the invention is finely ground and intimately mixed with the powdered excipients, lactose, corn stach, potato starch and magnesium stearate. The formulation is then compressed to afford tablets.

Example 32: Capsule Formulation

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<u>Ingredient</u>	<u>Amount per Capsule</u>	
Compound of the Invention	75.0mg	
Lactose		400.0mg
Magnesium Stearate		5.0mg

The compound of the invention is finely ground and mixed with the powdered excipients, lactose, corn starch and stearic acid, and then packed into two part, gelatin capsules.

Pharmacological Data

Based on studies to date, a positive correlation can be established between the ability of a compound to antagonise adenosine (purine) receptors and its activity in treating or preventing pathophysiological disorders arising from the cell surface effects of adenosine, such as heart block - (Cir . Res., 1982, 51, 569 et seq.) and asthma. Accordingly, a representative number of compounds of the present invention were tested for their ability to antagonise the purine receptors using the guinea pig ileum test system.

Procedure:-

Ilea were removed from sacrificed guinea pigs and placed in organ baths containing oxygenated Krebs-Henseleit buffer. After equilibration, the ilea were stimulated to contract (twitch contraction) us-

ing an electrical field-stimulus of 0.1 Hz, .05 ms duration and maximal voltage. Under these conditions, the twitch contraction results from the release of acetylcholine.

Concentration response curves to the purine agonist, 2-chloroadenosine, were determined first in the absence and then in the presence of multiple concentrations of the compounds of the invention. One concentration of each compound was used per tissue. Quantification of purine receptor antagonism was accomplished using the Schild regression technique, i.e. plots of $\log(\text{dose-ratio}-1)$ vs \log compound concentration, and the pA_2 determined by regression of the data points to the x-intercept, where $\log(\text{dose-ratio}-1)$ is zero. Since the slopes of these regressions were not different from unity, the pA_2 may be considered the pK_b , i.e. the negative log of the dissociation constant of the compound for the purine receptors.

Results:-

The compounds of the invention tested in this way and the results of each test are set forth below.

Compound of Example No.	pA_2 Guinea pig ileum (slope)
6	7.7 (0.9)
11	7.0 (1.0)
14	7.5 (1.0)

Compound of Example No.	pA_2 guinea pig ileum (slope)
15	7.1 (0.9)
18	7.1 (0.9)
19	7.45 (1.0)
THEOPHYLLINE	4.9 (1.1)

These results indicate clearly that the compounds of the present invention are capable of antagonizing adenosine receptors and that they are superior in their effect than the prior art adenosine antagonist, theophylline. The compounds of the present invention are, therefore, useful in the treatment or prophylaxis of pathophysiological disorders arising from the cell surface effects of adenosine.

Toxicity Data

The toxicity of a representative number of compounds of the present invention was determined by using the standard LD_{50} test. The compounds were administered intraperitoneally to mice and the results are set forth below.

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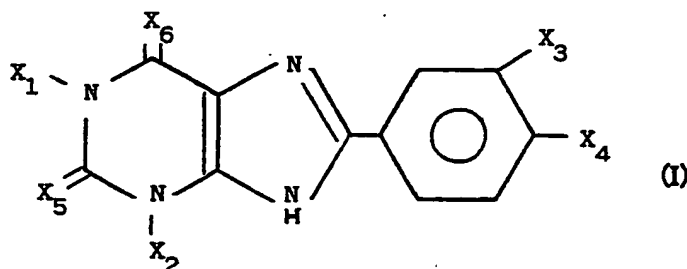
Compound of

Example No.LD₅₀ (mg/kg)

1	>500
6	>500
10	>100
12	>100
14	>100
16	>100
18	>100

Claims

1. A compound of formula (I):



wherein:

X₁ and X₂ are the same or different and are hydrogen, C₁₋₆ alkyl, C₂₋₆ alkenyl or C₇₋₁₂ aralkyl optionally substituted in the aryl ring by at least one substituent selected from C₁₋₆ alkyl, C₁₋₆ alkoxy, hydroxy, halo, nitro, amino and cyano, provided that both X₁ and X₂ are not hydrogen;

one of X₃ and X₄ is hydrogen, C₁₋₆ alkyl, trifluoromethyl, C₁₋₆ alkoxy, halo, nitro, amino, C₁₋₆ alkoxycarbonyl or carboxy and the other is a group -Y-Z where Y is C₂₋₆ alkenylene, or C₃₋₆ alkynyleneoxy, C₂₋₆ alkynylene or C₃₋₆ alkynyleneoxy and Z is carboxy, sulphonyl or phosphonyl or a C₁₋₆ alkyl ester, a C₇₋₁₂ aralkyl ester or a C₆₋₁₂ aryl ester thereof, or is 5-tetrazolyl; and

X₃ and X₄ are the same or different and are oxygen or sulphur, or a salt or solvate thereof.

2. A compound according to claim 1 wherein either or both of X₁ and X₂ are benzyl, optionally substituted in the aryl ring by at least one substituent selected from C₁₋₆ alkyl, C₁₋₆ alkoxy, hydroxy, halo, nitro, amino and cyano.

3. A compound according to claim 2 wherein the said optional substituents are selected from methyl, methoxy, hydroxy, chloro, nitro, amino and cyano.

4. A compound according to claim 3 wherein the optional substituents are selected from amino, nitro and cyano.

5. A compound according to any of claims 1 to 4

wherein X_1 and X_2 are selected from hydrogen and C_{1-6} alkyl.

6. A compound according to claim 5 wherein X_1 and X_2 are both C_{1-6} alkyl.

7. A compound according to any of claims 1 to 6 wherein one of X_3 and X_4 is hydrogen.

8. A compound according to claim 7 wherein X_3 is hydrogen.

9. A compound according to any of claims 1 to 8 wherein Y is C_{2-3} alkenylene or C_{2-6} alkynylene.

10. A compound according to claim 9 wherein Y is vinylene or acetylene.

11. A compound according to any of claims 1 to 10 wherein Z is an ester selected from the methyl, ethyl, benzyl and phenyl esters.

12. A compound according to any of claims 1 to 10 wherein Z is carboxy or a C_{1-6} ester thereof.

13. A compound according to any of claims 1 to 6 wherein X_3 is hydrogen and X_4 is -Y-Z when Y is vinylene and Z is carboxy.

14. A compound according to any of claims 1 to 13 wherein X_3 and X_4 are both oxygen.

15. A compound selected from the following compounds:-

(E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-1-propyl-9H-purin-8-yl)cinnamic acid.

(E)-4-(1,3-diethyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(1,3-diallyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)cinnamic acid,

(E)-4-(1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(3-ethyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid, H-

(E)-4-(1,2,3,6-tetrahydro-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid,

5 (E)-4-(1,2,3,6-tetrahydro-3-isobutyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid,

10 (E)-4-(1,2,3,6-tetrahydro-3-isobutyl-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(1-ethyl-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

15 (E)-4-(1,3-dibutyl-1,2,3,6-tetrahydro-1,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(1,3-dibenzyl-1,2,3,6-tetrahydro-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(3-butyl-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

25 (E)-4-(1-butyl-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

(E)-4-(3-benzyl-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

30 (E)-4-(1,2,3,6-tetrahydro-1,3-diisobutyl-2,6-dioxo-9H-purin-8-yl)cinnamic acid,

35 (E)-4-(1,2,3,6-tetrahydro-1,3-dimethyl-6-oxo-2-thio-9H-purin-8-yl)cinnamic acid,

(E)-4-[3-(4-cyanobenzyl)-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl]cinnamic acid,

40 (E)-4-[3-(3-cyanobenzyl)-1,2,3,6-tetrahydro-1-methyl-2,6-dioxo-9H-purin-8-yl]cinnamic acid,

3-[4-(1,2,3,6-tetrahydro-2,6-dioxo-1,3-dipropyl-9H-purin-8-yl)phenyl]propionic acid,

45 (E)-4-[1-(4-cyanobenzyl)-1,2,3,6-tetrahydro-3-methyl-2,6-dioxo-9H-purin-8-yl]cinnamic acid,

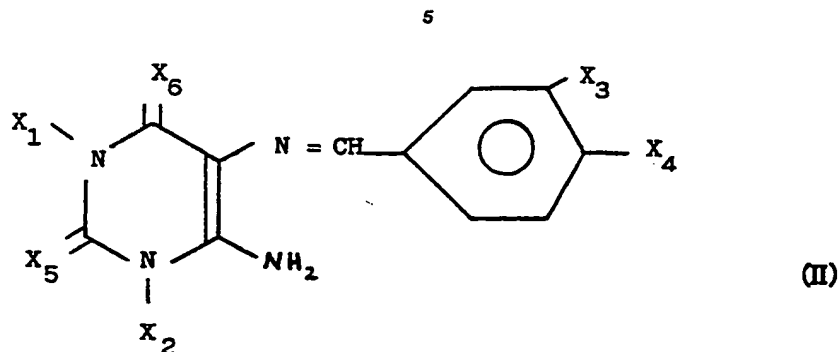
50 (E)-4-(1-benzyl-1,2,3,6-tetrahydro-2,6-dioxo-3-propyl-9H-purin-8-yl)cinnamic acid, and

(E)-4-(3-benzyl-1,2,3,6-tetrahydro-2,6-dioxo-1-propyl-9H-purin-8-yl)cinnamic acid.

55 16. A process for the preparation of a compound of formula (I) as defined in claim 1 or a salt or solvate

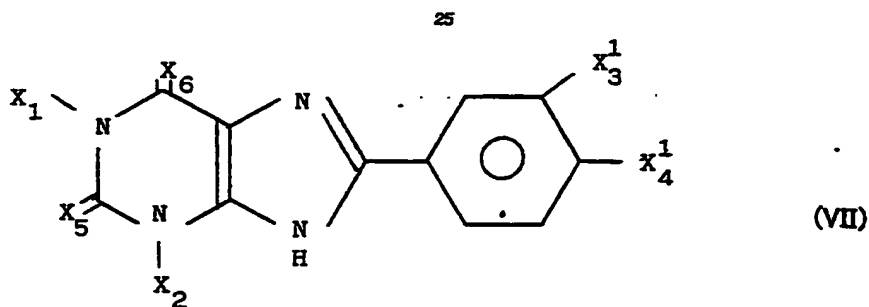
thereof comprising;

A) cyclising, in the presence of an oxidant, a compound of formula (II):



wherein X_1 and X_6 are as defined in claim 1; or

B) where Y is C_{3-6} alkenyleneoxy or C_{3-6} alkynyleneoxy, reacting a compound of formula (VII):

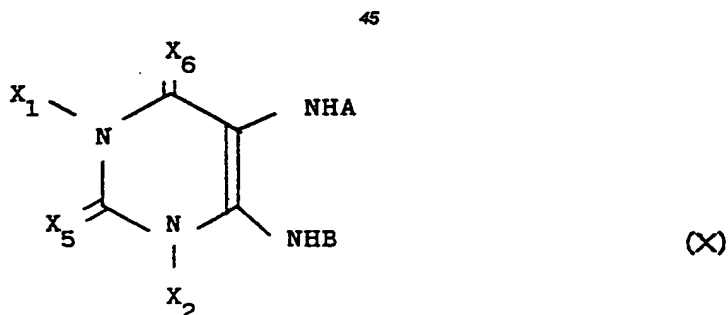


wherein X_1 , X_2 , X_5 and X_6 are as defined in claim 1 and one of X_3^1 and X_4^1 is as defined in claim 1 for one of X_3 and X_4 respectively and the other is hydroxy, with a compound of formula (VIII);

L-Y'-Z (VIII)

wherein L is a leaving group, Y' is C_{3-6} alkenylene or C_{3-6} alkynylene and Z is as defined in claim 1; or

C) cyclising a compound of formula (X):



wherein X_1 , X_2 , X_3 and X_4 are as defined in claim 1 and one of A and B is hydrogen and the other is 3-(X_3)-4-(X_4)-benzoyl in which X_3 and X_4 are as defined in claim 1;

and thereafter, or simultaneously therewith, optionally (i) converting any of the groups X_1 to X_4 in the resulting compound of formula (I) into a different group X_1 to X_4 respectively, and/or (ii) forming a salt or solvate thereof.

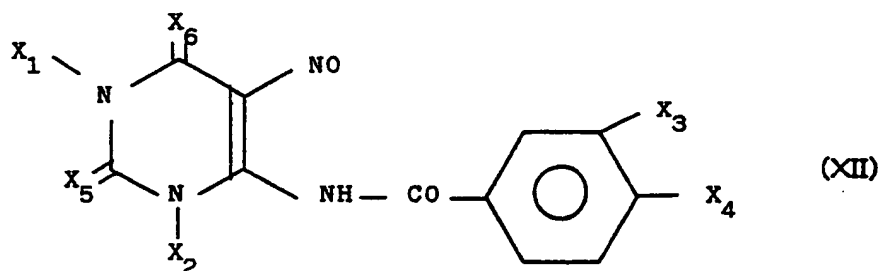
17. A pharmaceutical composition comprising a compound as claimed in any of claims 1 to 15 together with a pharmaceutically acceptable carrier therefor.

18. A compound as claimed in any of claims 1 to 15, for use in therapy.

19. A compound according to claim 18 for use in the treatment or prophylaxis of pathophysiological conditions arising from the cell-surface effects of adenosine.

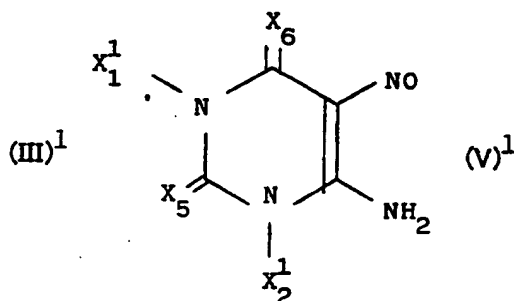
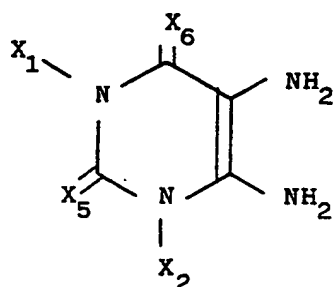
20. A compound according to claim 18 for use in the treatment or prophylaxis of heart block, asthma or irritable bowel syndrome.

21. The compounds of formulae (II) and (X) as defined in claim 16, and also the compound of formula (XII):



wherein X_1 to X_4 are as defined in claim 1;

the compounds of formulae (III)¹ and (V)¹:



wherein X_1 ¹ is methyl and X_2 ¹ is propyl, X_1 ¹ is propyl and X_2 ¹ is methyl, X_1 ¹ is *n*-butyl and X_2 ¹ is methyl, X_1 ¹ and X_2 ¹ are both *iso*-butyl, X_1 ¹ and X_2 ¹ are both allyl, or X_1 ¹ and X_2 ¹ are the same or different and are C_{7-12} alkyl optionally substituted in the aryl

ring by C_{1-6} alkyl, C_{1-6} alkoxy, hydroxy, halo, nitro, amino or cyano; and

the compound of formula (VII)¹:

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(VII)¹

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wherein X₁ⁿ and X₂ⁿ are the same or different and are hydrogen, C₂₋₆ alkyl, C₂₋₆ alkenyl or C₇₋₁₂ aralkyl optionally substituted in the aryl ring by C₁₋₆ alkyl,

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C₁₋₆ alkoxy, hydroxy, halo, nitro, amino or cyano, and X₃¹ and X₄¹ are as defined; and salts and solvates thereof.

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